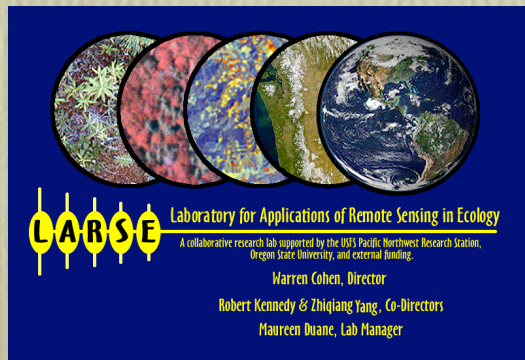


# The promise of an open Landsat archive: A new era for landscape monitoring and management?

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Robert E. Kennedy<sup>1</sup>  
Warren B. Cohen<sup>2</sup>  
Zhiqiang Yang<sup>1</sup>



<sup>1</sup> Department of Forest Ecosystems and Society / Oregon State University

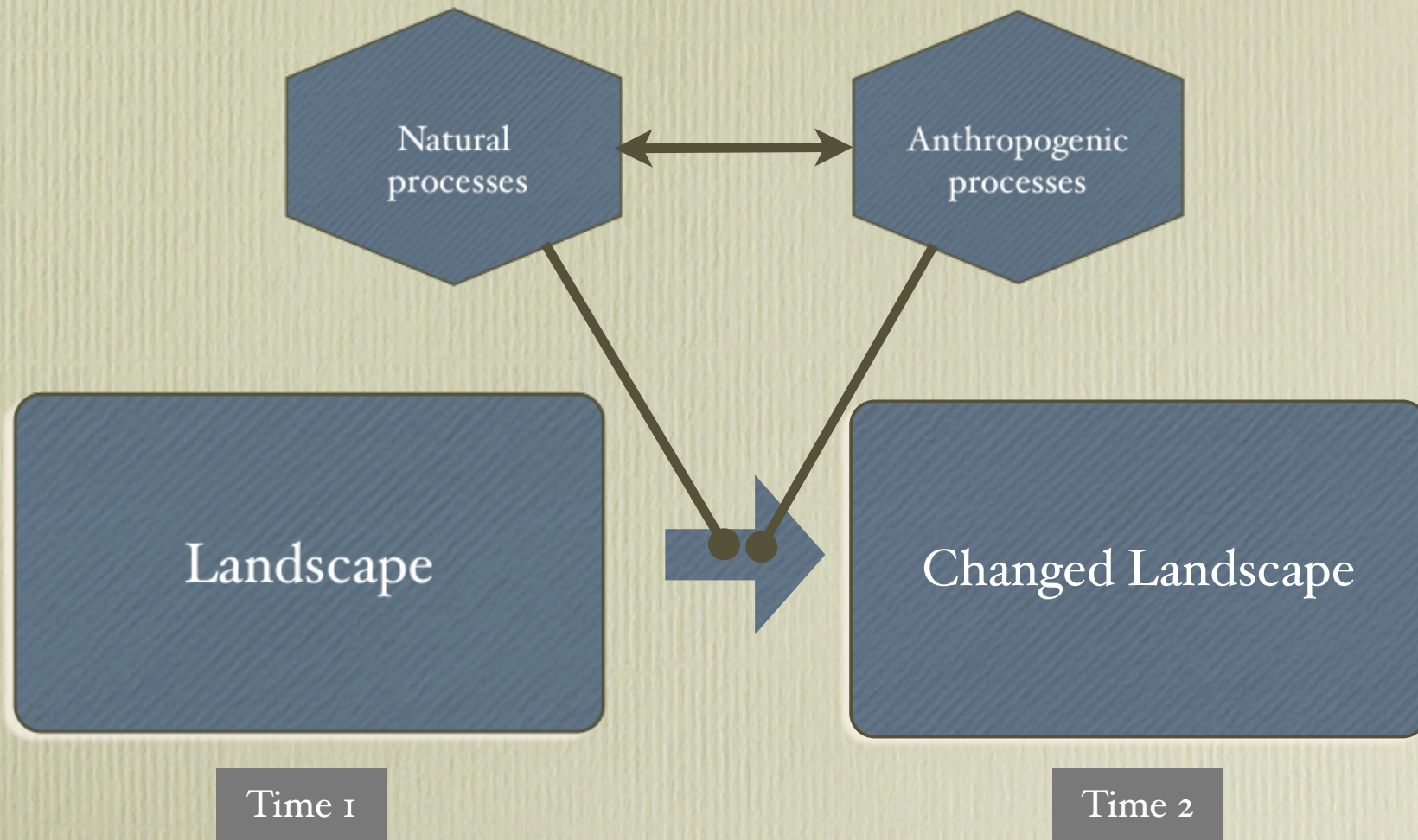
<sup>2</sup> USDA Forest Service / PNW Research Station

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Laboratory for Applications of Remote Sensing in Ecology  
[www.fsl.orst.edu/~larse](http://www.fsl.orst.edu/~larse)

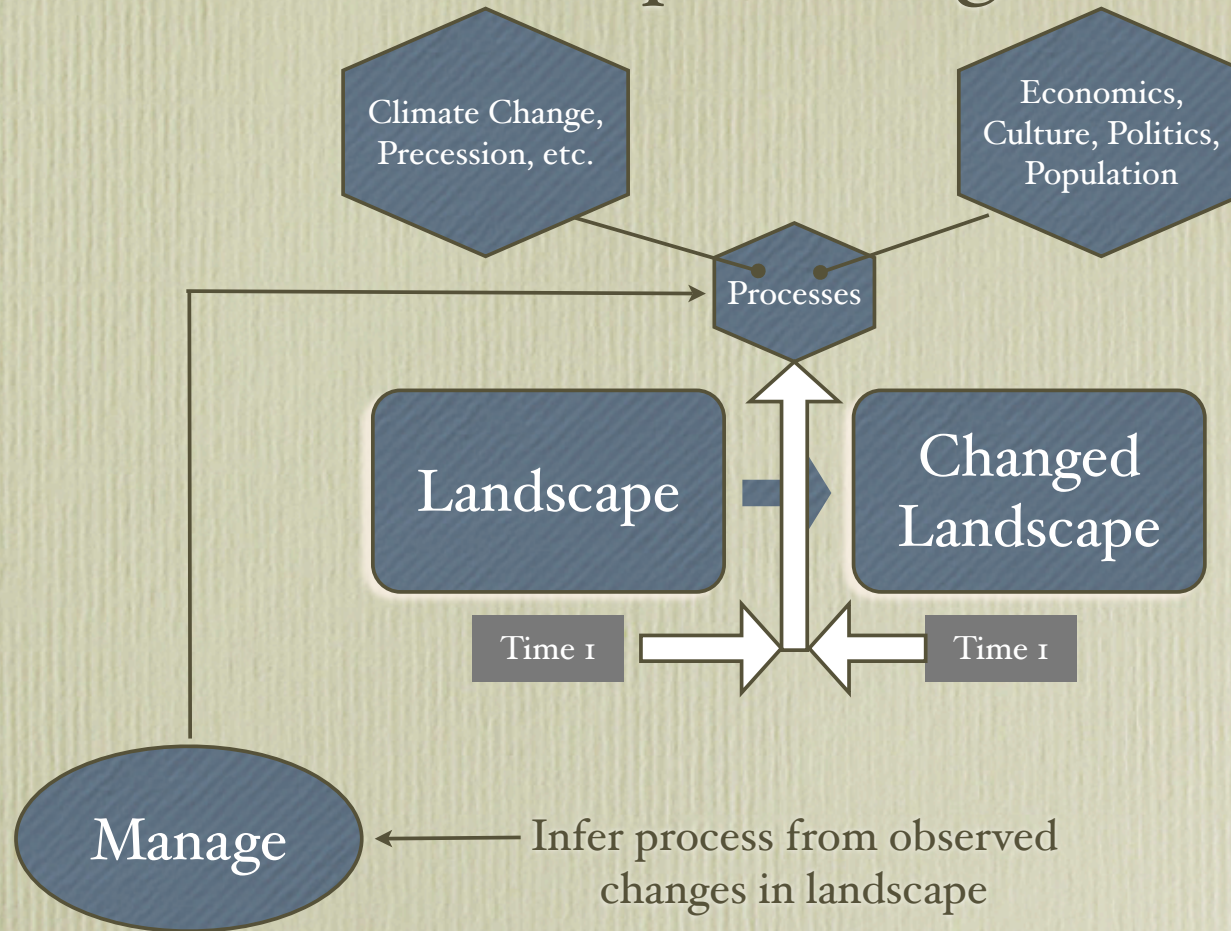


# Landscape monitoring





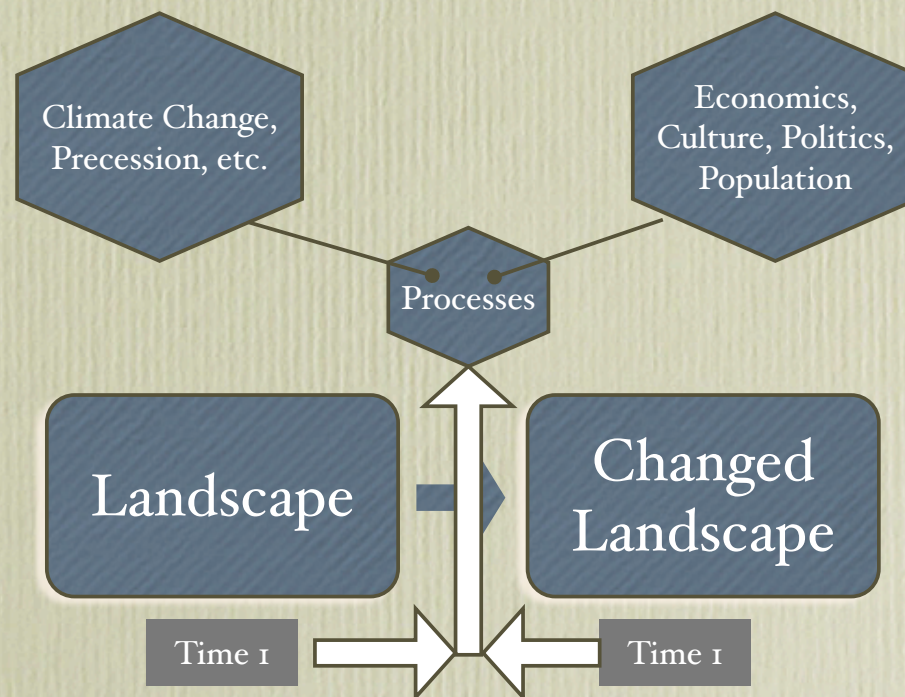
# Landscape management





# Landscape monitoring and management

Our ability to understand processes and drivers,  
and to then manage for them, depends on  
*how well we can track the changes over time*





# The Open Landsat Archive

- Landsat-quality data already used in many natural resource / landscape analyses
- Open access means a new data paradigm -- yearly or sub-yearly stacks.

*But will open access to archive simply mean cheaper paths to the same types of product, or will it allow fundamentally new information to be obtained?*



# New sources of information

- Frequency:
  - Capture the same phenomena with frequencies commensurate with potential drivers
- Sensitivity:
  - Detect more-subtle change with increased signal-to-noise ratio afforded by dense temporal stacks
- Trajectory:
  - Identify new processes and dynamics by tracking the evolution of signatures over time



# Current Projects

that tap information content of yearly TM stacks:

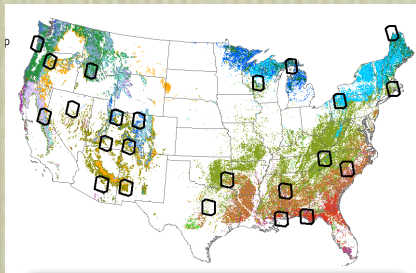
<i>Project</i>	<i>Funder</i>	<i>Goal</i>
North American Forest Disturbance since 1972 (NAFD)	NASA	Yearly disturbance in forests, national scale
Northwest Forest Plan (NWFP) forest disturbance mapping	USDA Forest Service	Yearly clearcuts/thinning/insects/fire disturbance in forests, regional scale
Protocol development Sierra Nevada and Colorado Plateau National Parks (SIEN, CP)	NPS	Track all landscape dynamics in several national parks in CA, AZ, NM, and CO, in support of overall park monitoring
Synthesis of Remote Sensing and Field Observations to Model and Understand Disturbance and Climate Effects on the Carbon Balance of Oregon, Washington, and California (ORCA II)	DOE	Bottom-up and top-down characterization of carbon dynamics
Leveraging temporal variation in climate and management across national parks in the western U.S. to characterize three decades of landscape vegetation dynamics (NIP)	NASA	Map landscape dynamics in parks in AK, WA, CA, NM, AZ; link with management and cyclic climate oscillations
Mapping current conditions and modeling the dynamic responses of riparian vegetation and salmon habitat in Oregon (OWEB)	OWEB	Link yearly disturbance dynamics, lidar-based height and structure into hydrological and stand modeling paradigm



# Forest disturbance: National scale

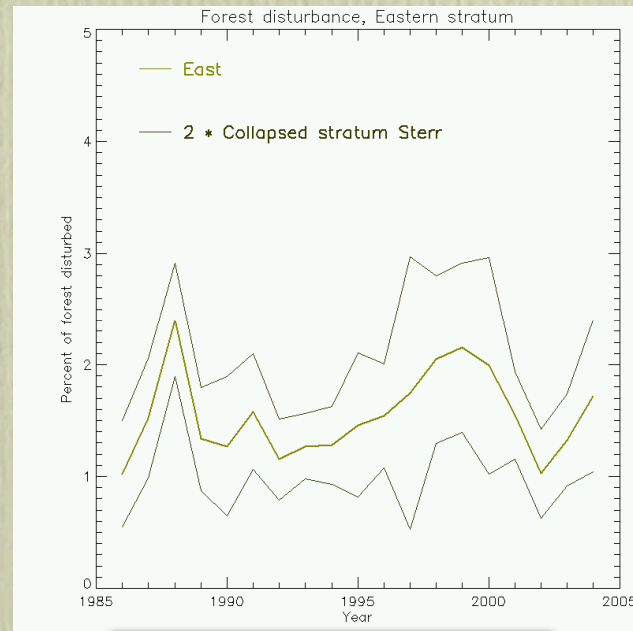
- Landsat-based estimates of national forest disturbance (area / year)
- Source: VegTracker (Huang et al. *in review*)
- Uses: Carbon modeling; understanding economic drivers

Frequency  
Sensitivity  
Trajectory

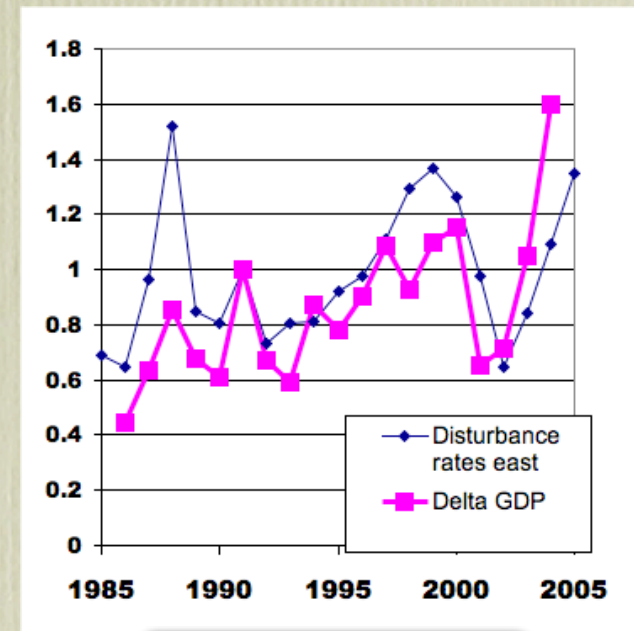


Sample based estimation

Project: NAFD



Note: Provisional estimates

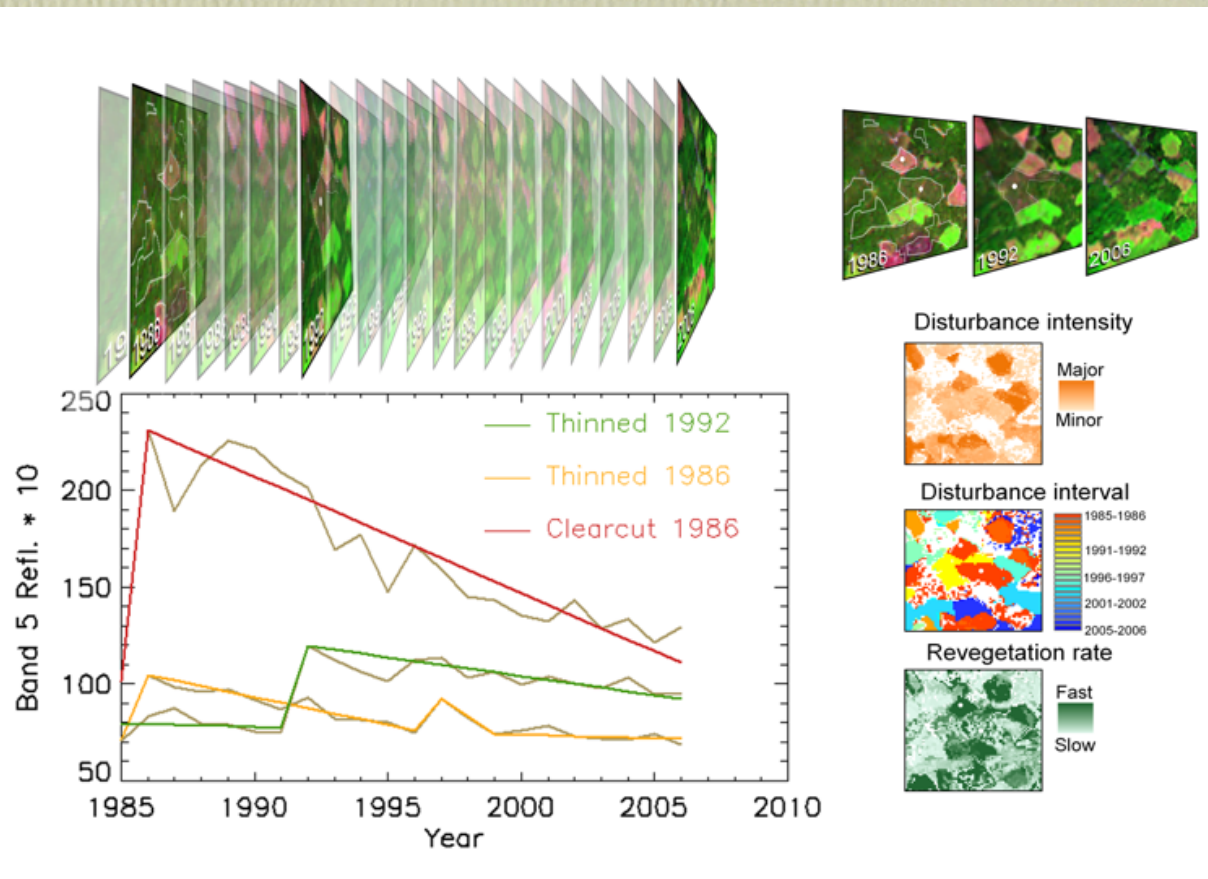


Scaled rates vs. GDP



# Tool: LandTrendr

## *Landsat Detection of Trends in Disturbance and Recovery*



Build stack

Radiometric  
normalization

Cloud masking

Segmentation

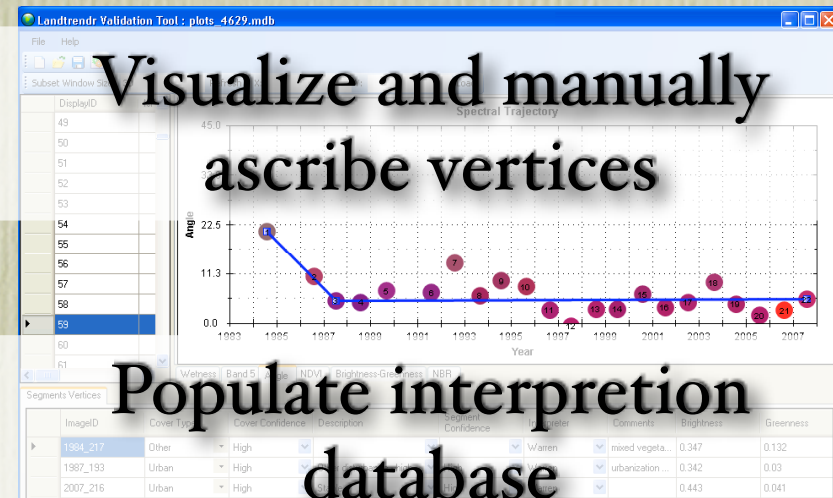
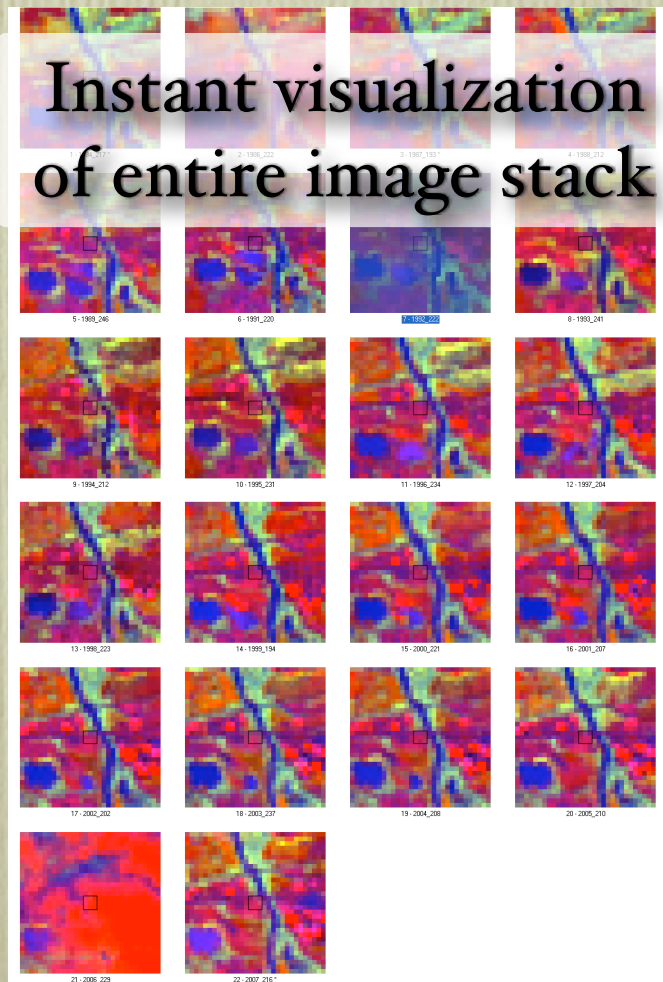
Labeling, filtering

- Time-series segmentation: “The life of a pixel”



# Tool: TimeSync

- Interpretation / “validation” tool for TM/MSS stacks

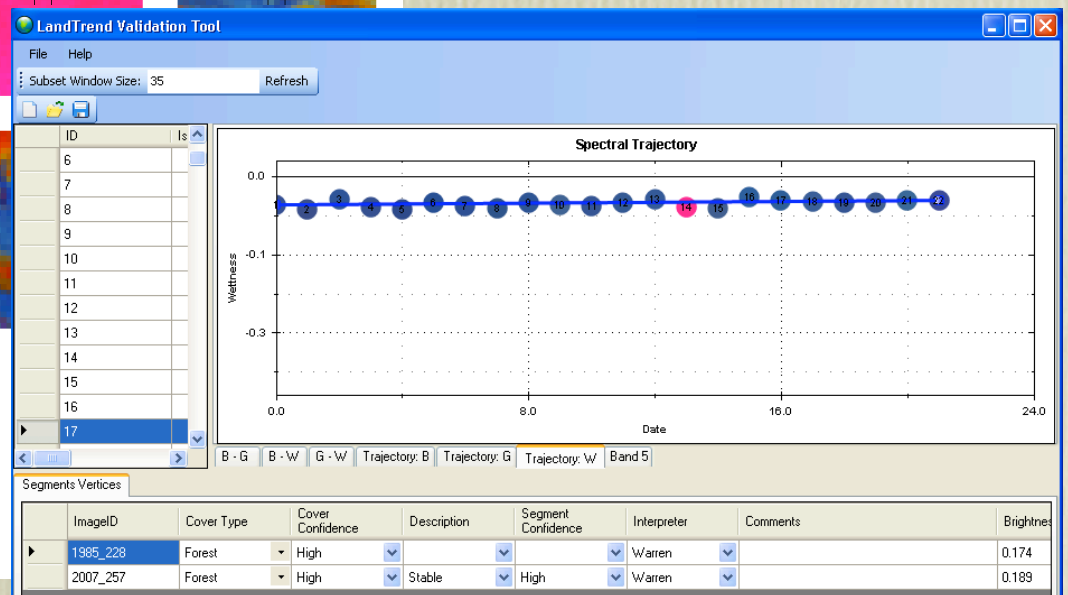
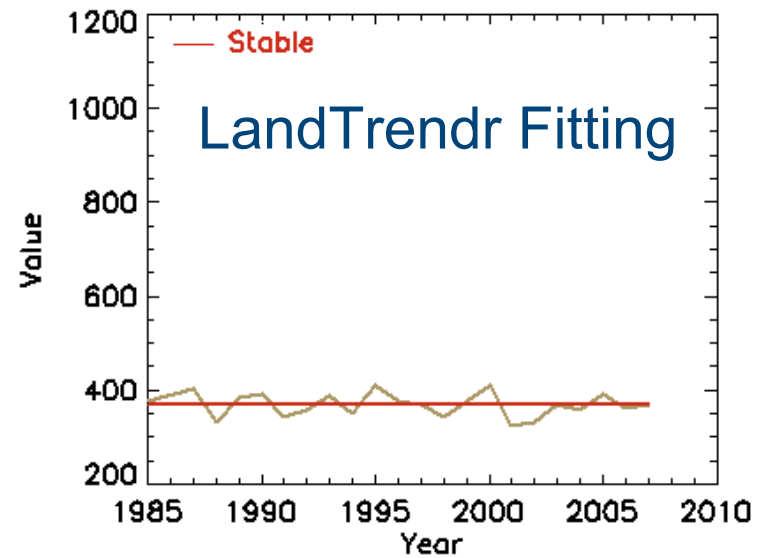
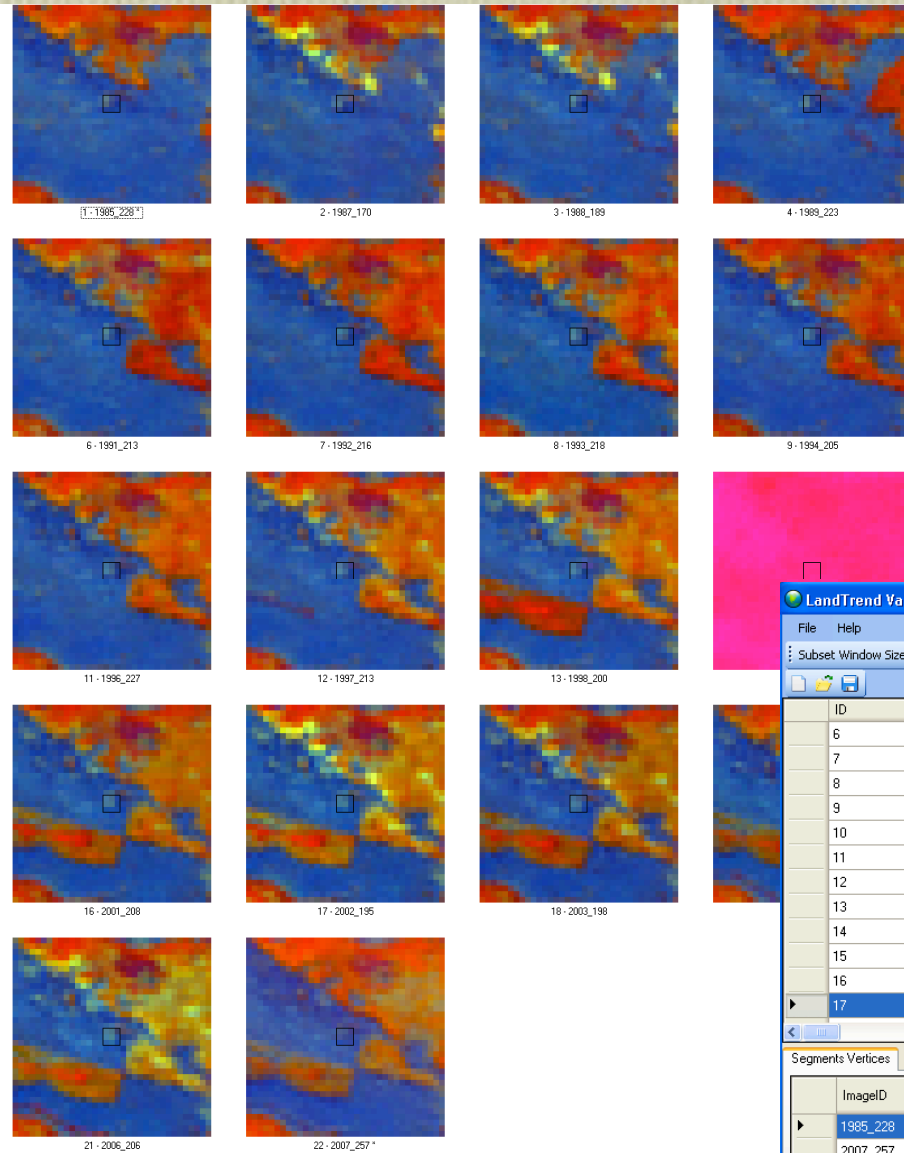


**Link with GoogleEarth for corroboration & percent cover estimates**

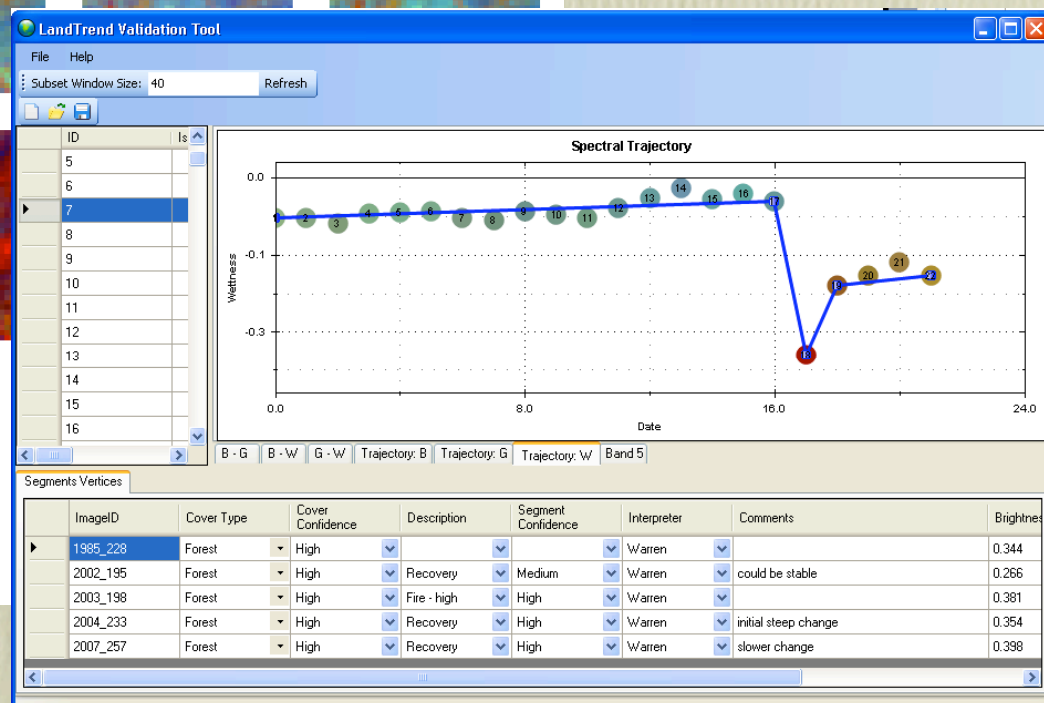
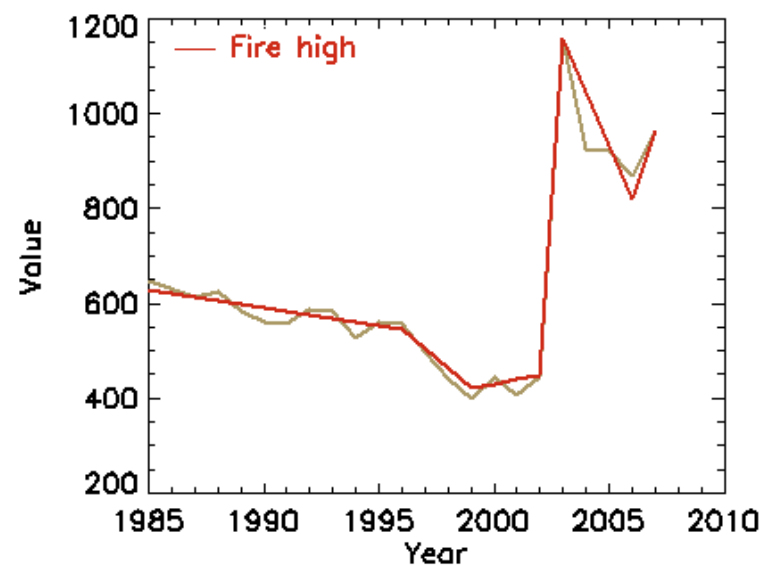
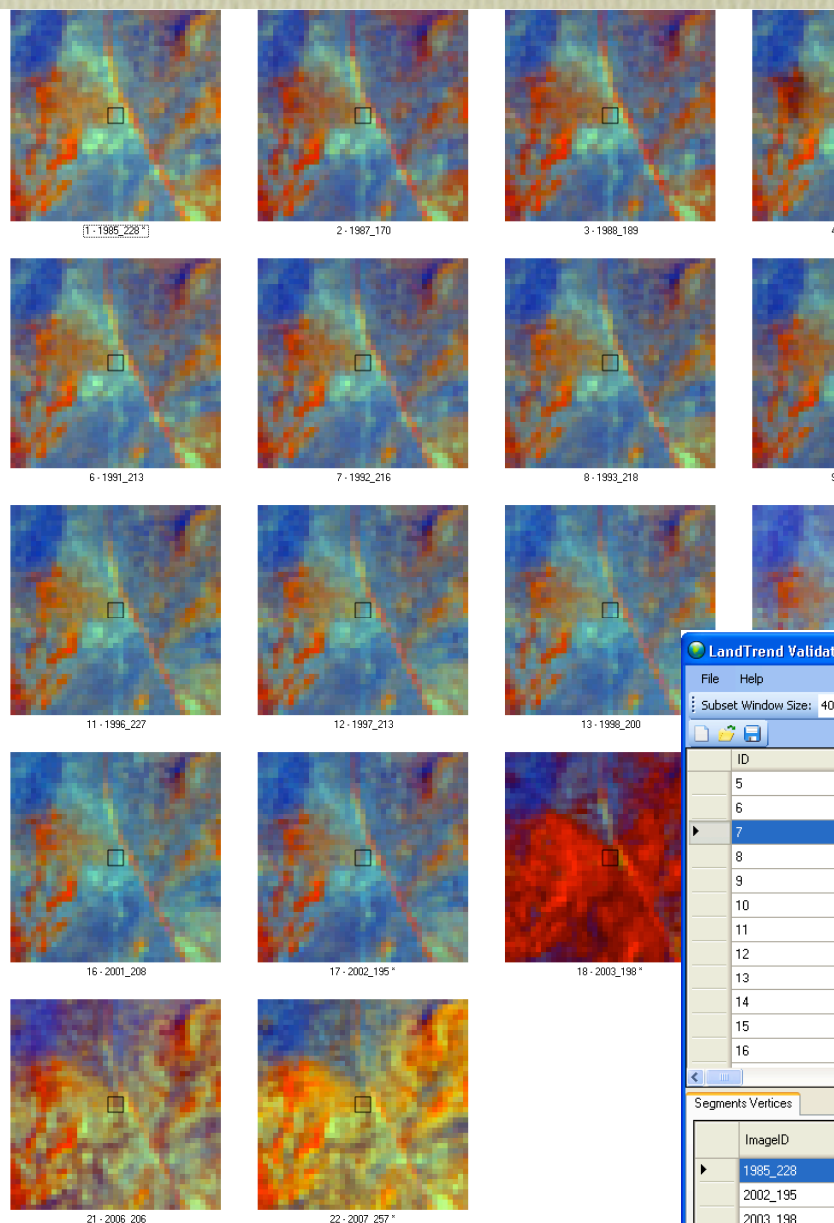




# Example trajectories



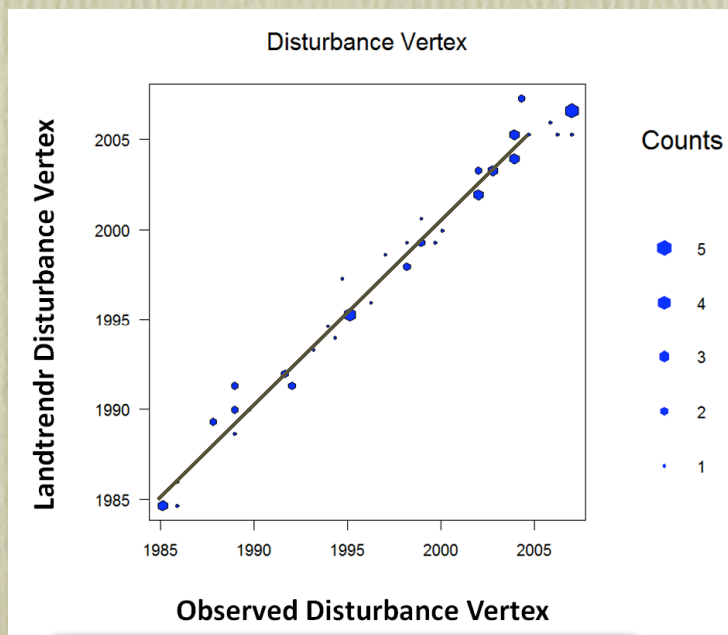




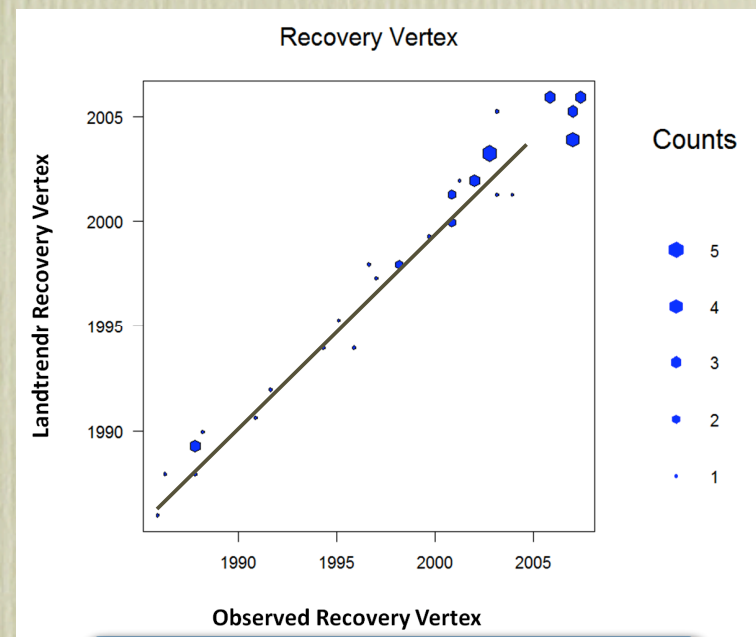


# Vertex comparison

- New methods needed to compare datasets: ongoing efforts
- Fuzzy vertex comparison? Compare onset of overlapping segments



Average offset: 0.57 years  
Not w/in 3 yrs: 26%



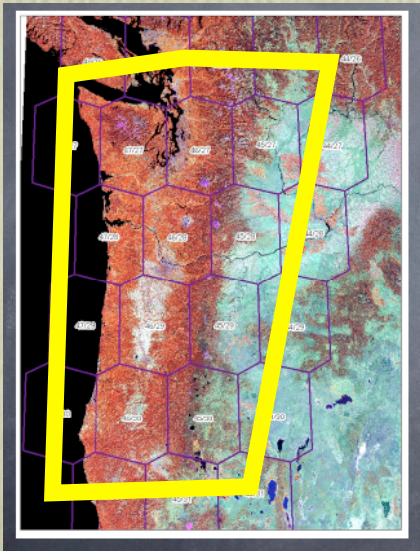
Average offset: 0.91 years  
Not w/in 3 yrs: ~22%



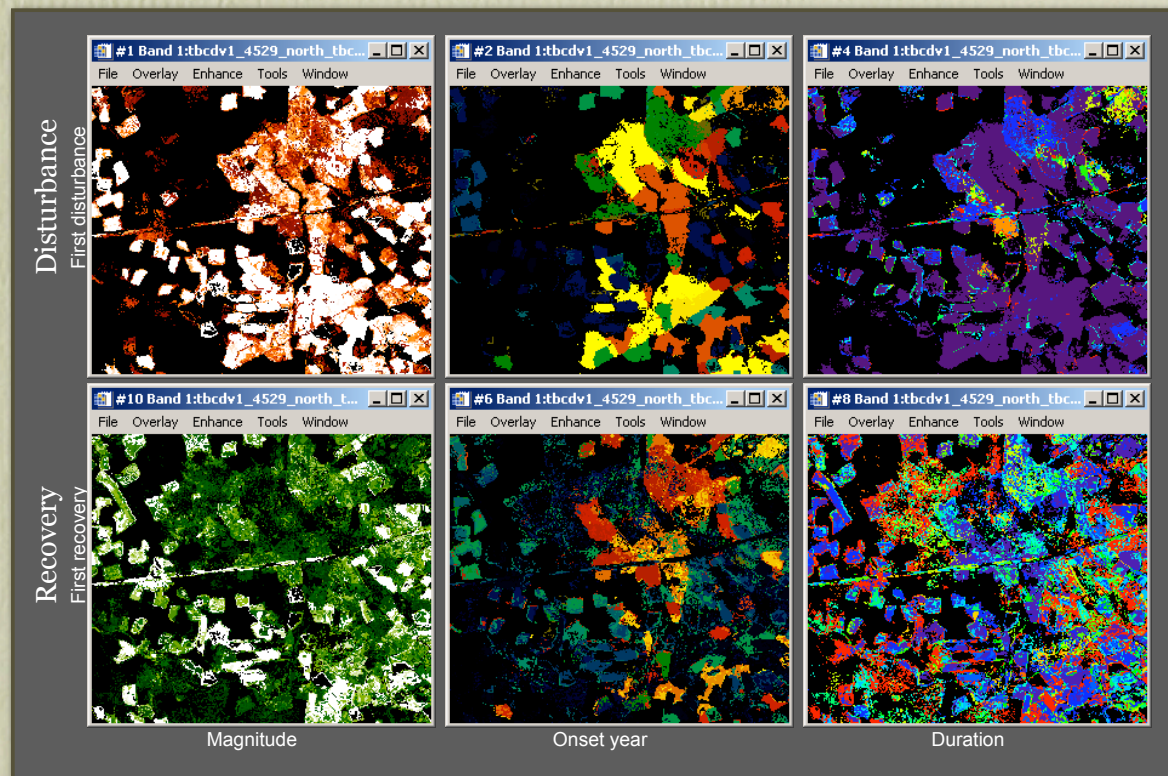
# Forest dynamics: Regional scale

- Landsat-based yearly maps of disturbance 1985-2007
- Label: Thinning, clearcut, insect, fire, multiple disturb.
- Source: LandTrendr + TimeSync
- Uses: Spotted Owl habitat monitoring

Frequency  
Sensitivity  
Trajectory



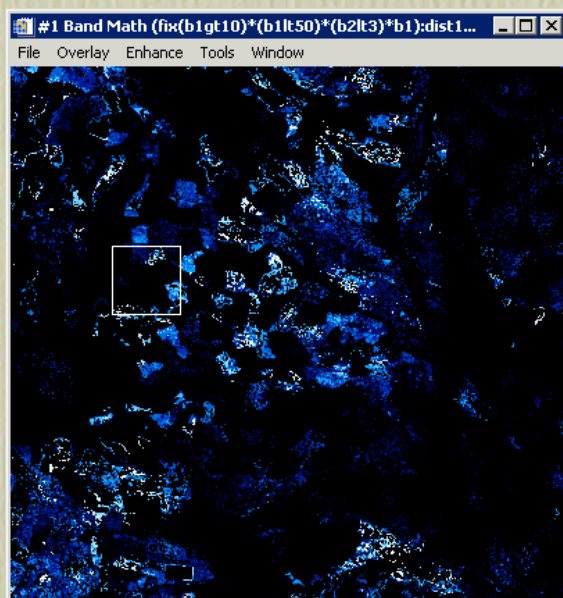
Project: NWFP



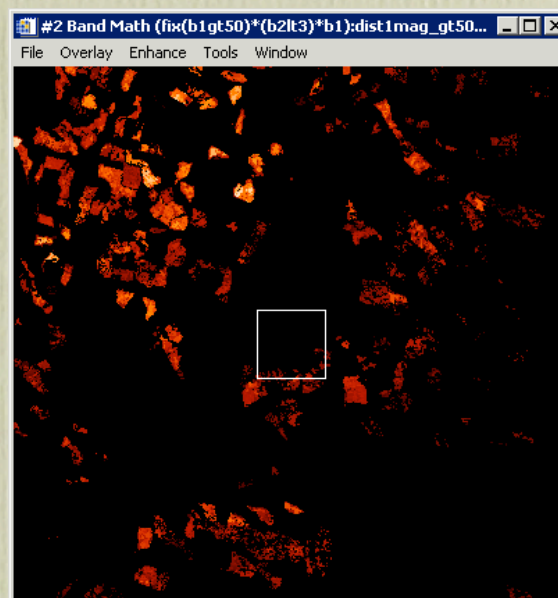


# Forest dynamics: Regional scale

- Link with TimeSync-interpreted percent cover models
- Richness of outputs allows flexible query of database
  - Brings us one step closer to *process*
  - Example: Separate high-intensity, abrupt disturbance from moderate intensity, abrupt disturbance



Loss of 10-50% absolute veg cover,  
Duration 1 or 2 years



Loss of >50% absolute veg cover,  
Duration 1 or 2 years

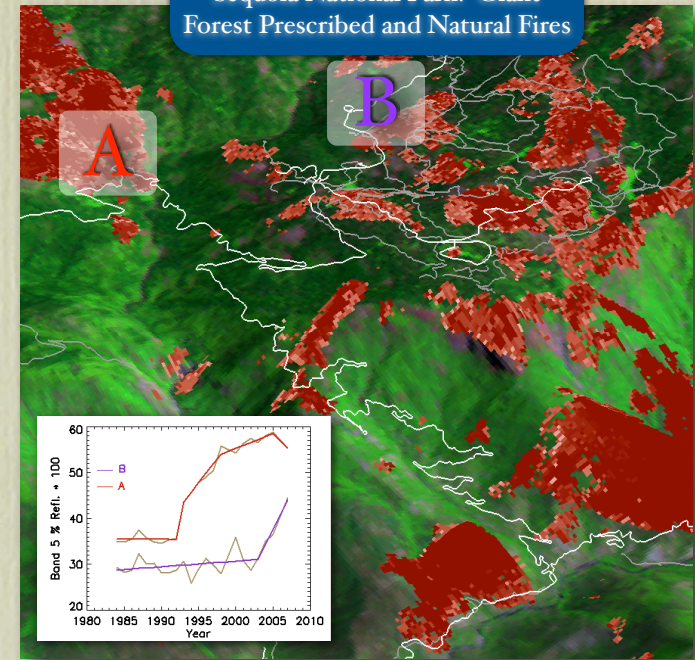


# Prescribed burns: Sequoia National Park

- Underburns in Sequoia groves not discernible with two-date change approaches (dNBR)
- Post-fire trajectory may be diagnostic, however (B)
- Post-fire effects also apparent in wildfire (A)
- Multiple underburns detectable

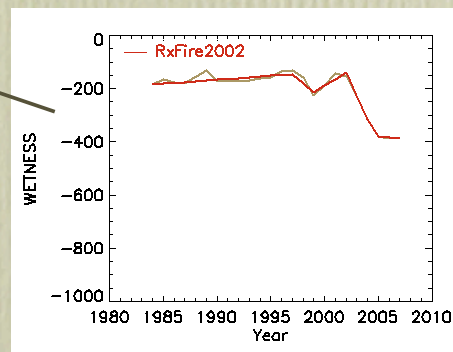
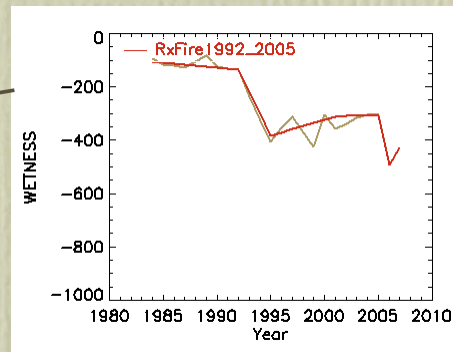
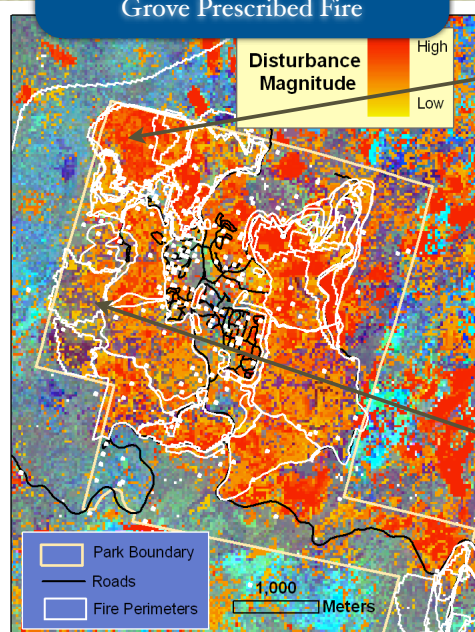
Frequency  
Sensitivity  
Trajectory

Sequoia National Park: Giant  
Forest Prescribed and Natural Fires



Projects: SIEN, NIP

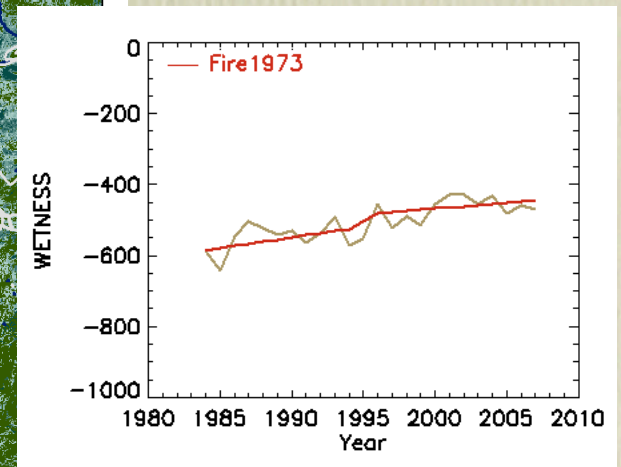
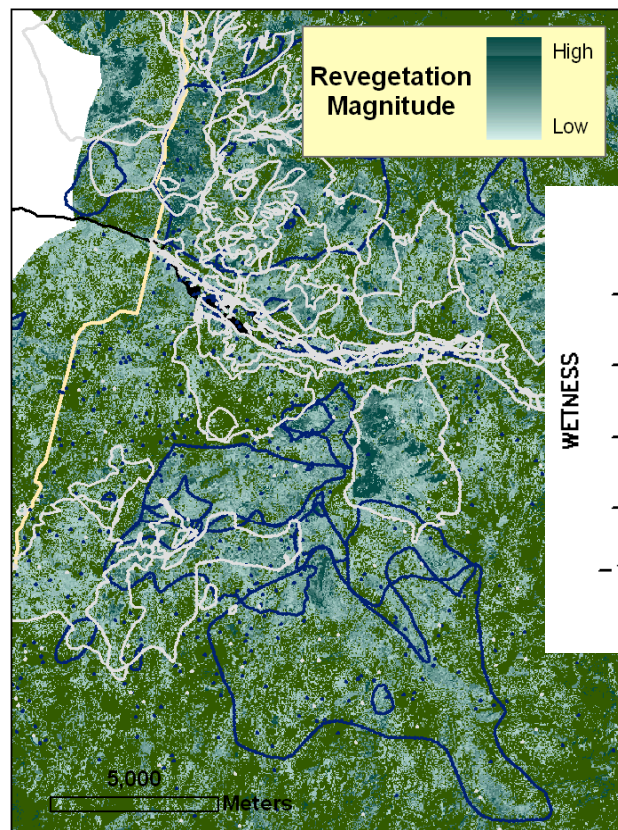
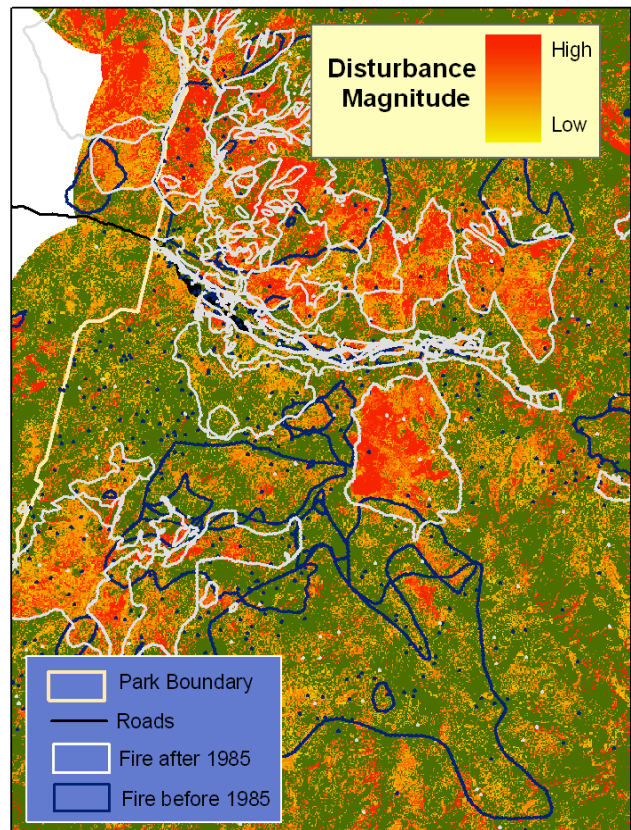
Sequoia National Park: Grant  
Grove Prescribed Fire





# Post-disturbance recovery

- Identify older disturbance patterns
- Constrain recovery rates from models, examine landscape-scale controls on recovery rate

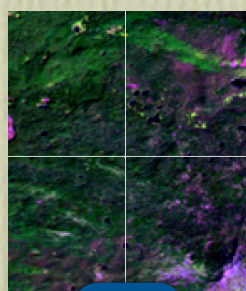




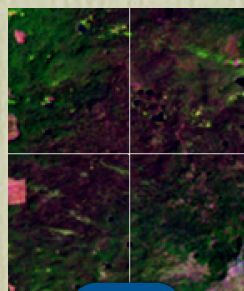
# Insect mortality

- Trajectory information critical to identify insect-related mortality
- Spatial patterns corroborated by forest health monitoring (FHM) overflight data
- Uses: carbon, habitat, resource, recreation

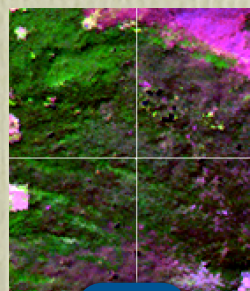
Frequency  
Sensitivity  
Trajectory



1985

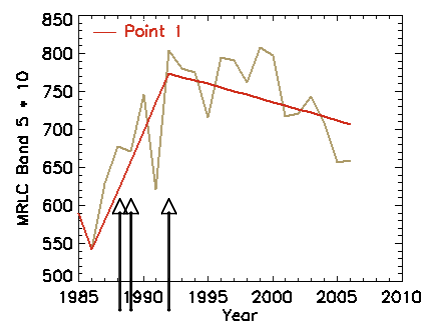


1996



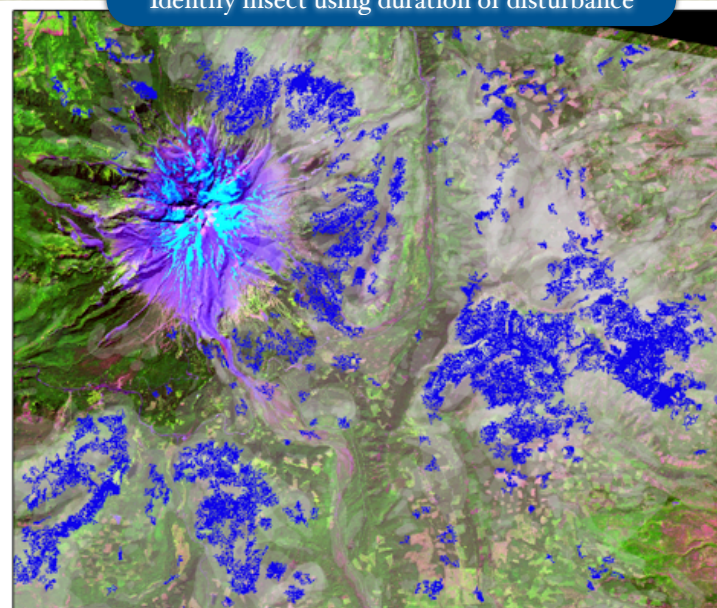
2002

Projects: NWFP,  
NIP, SIEN



FHM Detections

Identify insect using duration of disturbance





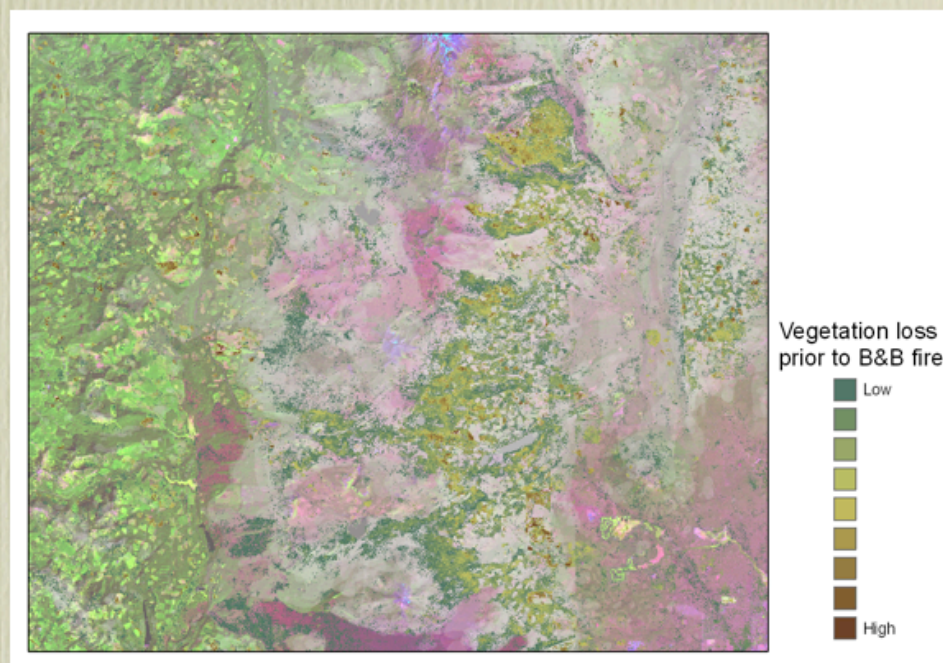
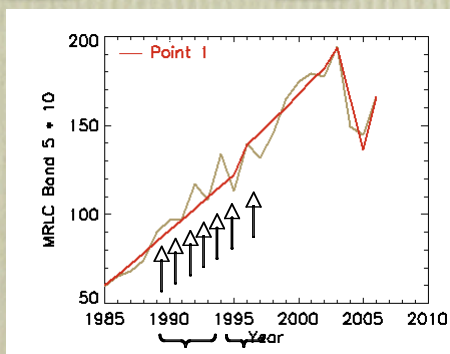
# Insect + Fire

- Identify insect mortality that precedes fire
- Feedbacks among multiple interacting disturbance processes
- Uses: Carbon, climate change effects, resource, recreation

Frequency  
Sensitivity  
Trajectory



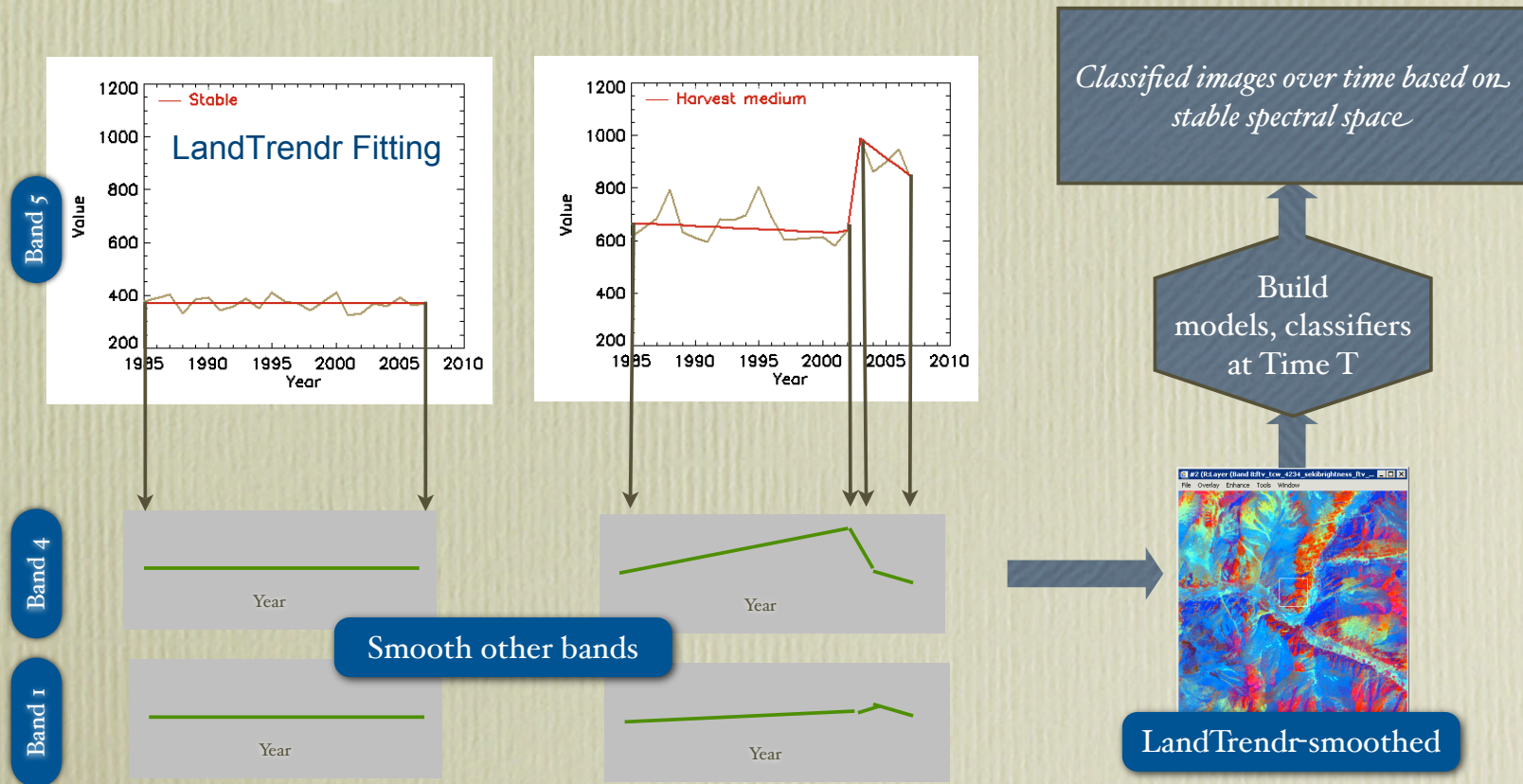
Projects: NIP





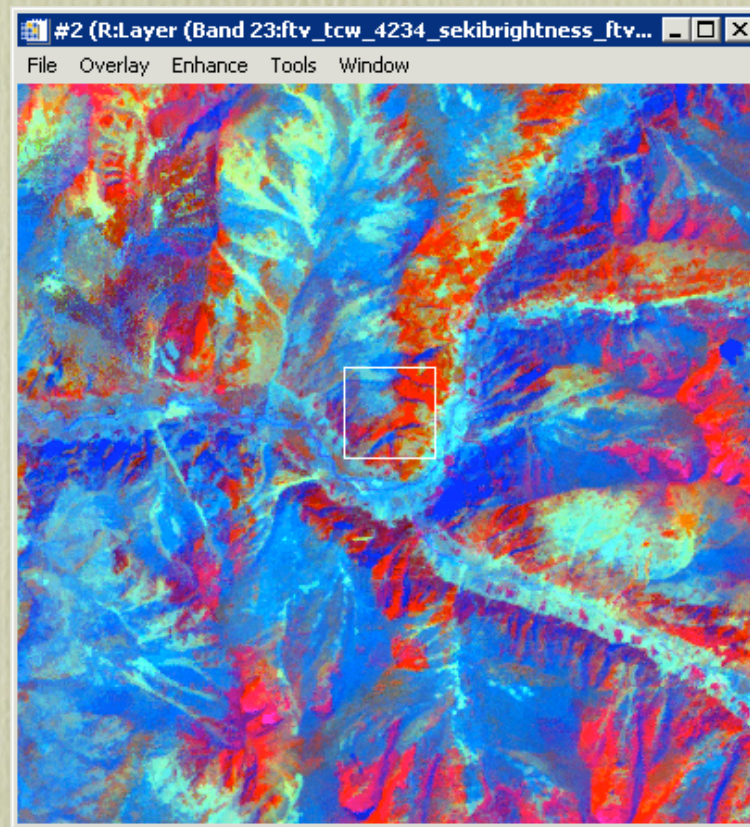
# Everything

- National parks must track everything everywhere all the time
- Track entire spectral space, apply classifiers, models, etc.
- Temporal smoothing: Segment using single index, fit other indices using vertices



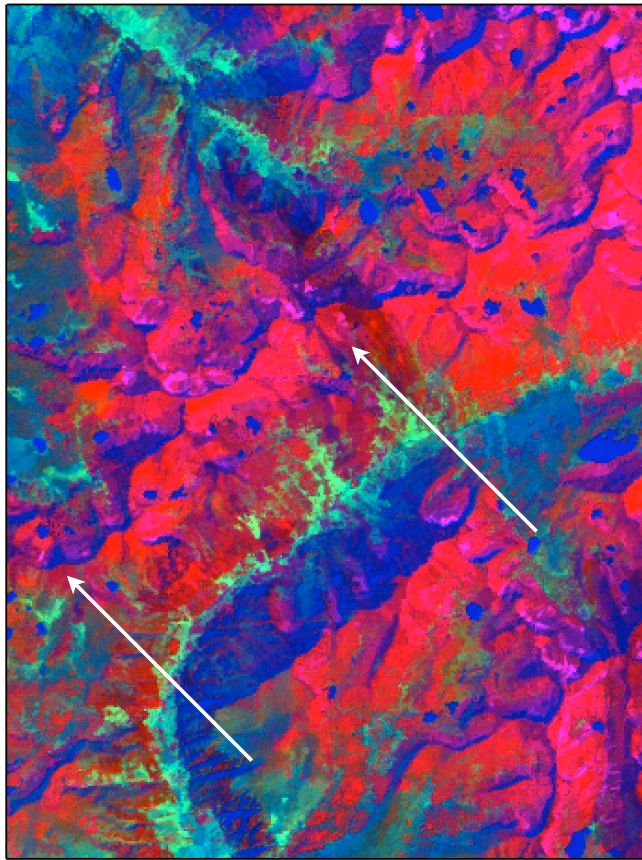


# Fitted tasseled-cap images through time



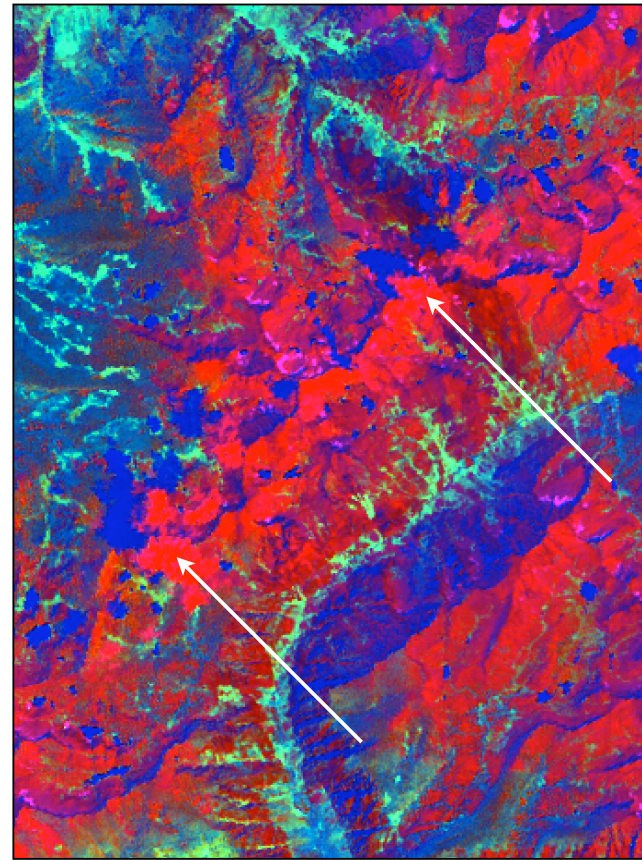


# Side benefit: Clouds



fitted to 2002

LandTrendr-smoothed image



madcal'd 2002

Original tasseled-cap image



# Summary

- Stacks of imagery allow new tools and approaches
- Frequency, subtlety, and trajectory information can be tapped for new uses
- Inference of agent/process improved over traditional two-date change detection approaches
- Let the new era begin!



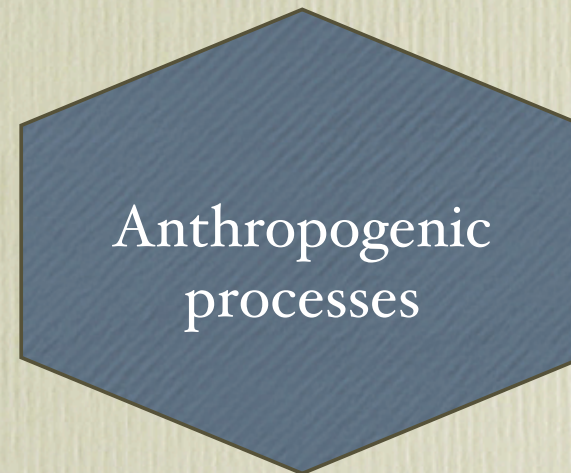
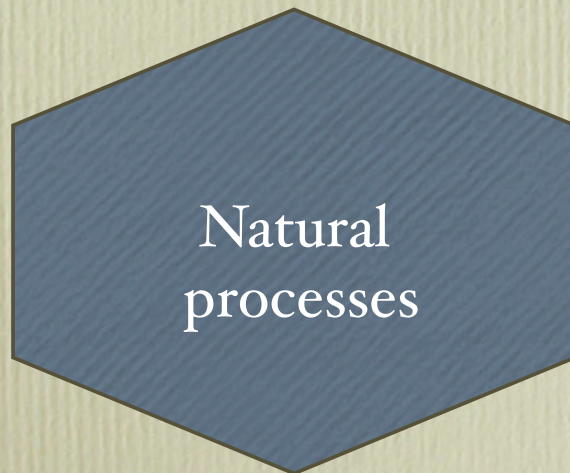
# PIECES

## Services

Resources (food, fiber, fuel, etc.)  
Habitat (for humans and critters)  
Water (potential/actual stores)  
Nutrients (C, N, P, K)  
Enjoyment (recreation, aesthetic)

## Landscape



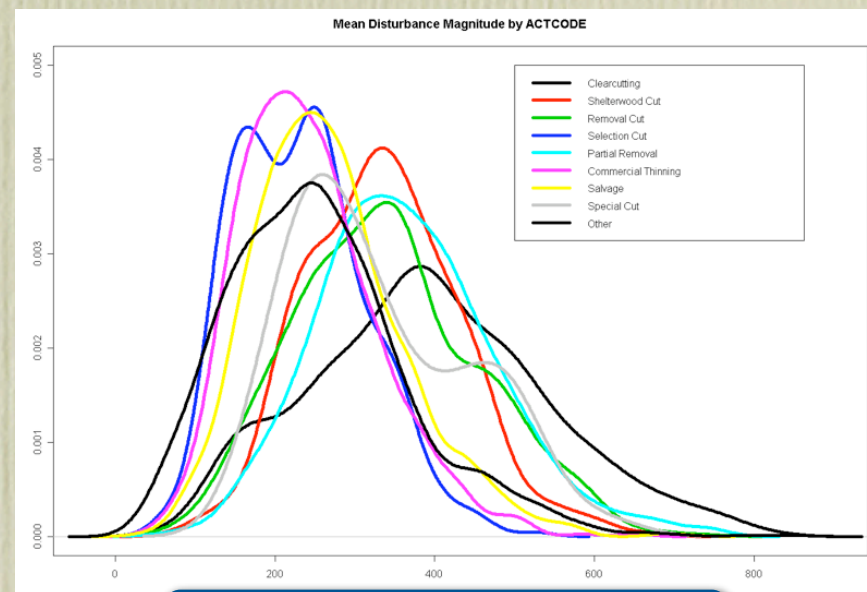
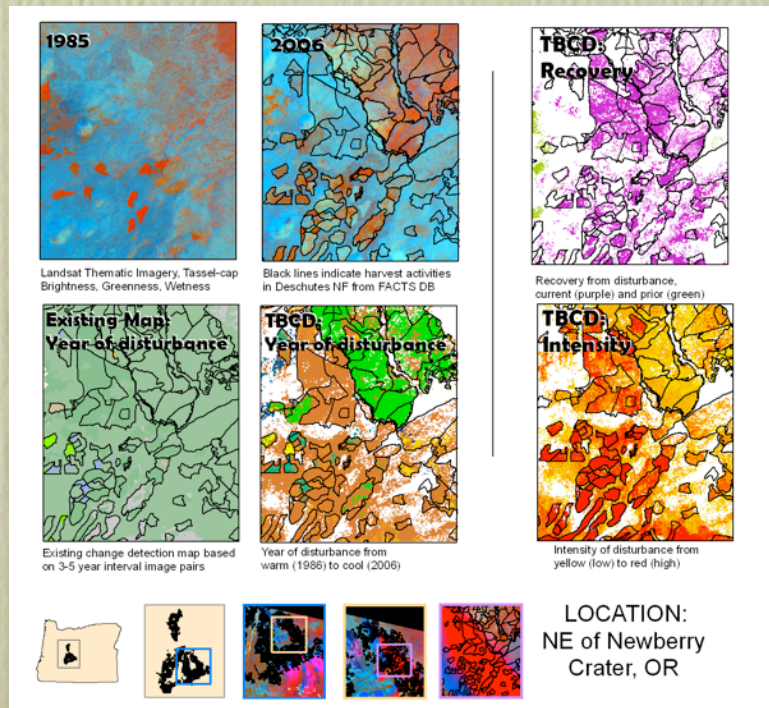




# Forest disturbance: National forest scale

- Trajectory-based approaches have potential to augment/improve USDA FACTS database
- Pros: Consistent measurement units across ownerships; standardized definitions; recovery rates and non-management disturbance captured as well

Frequency  
Sensitivity  
Trajectory



Disturbance magnitude related to activity code in database



# Carbon modeling; Hydrology/Habitat

- Feed yearly disturbance into Biome-BGC framework
  - Separate by disturbance type and severity
    - Implications for C removal rate and recovery
- Feed LandTrendr trajectory information into Dynamic Riparian and Aquatic Integrated Network model
  - Investigate use of LandTrendr to augment/extend structure information from small-footprint lidar

Frequency  
Sensitivity  
Trajectory

Projects: ORCA II,  
OWEB



**Trajectory-based change detection:  
Extracting forest disturbance within agriculture**

